INJECTION ENERGY OF THE 5 Hz BOOSTER

R. Billinge, Q. Kerns, L. Teng, G. Tool, A. van Steenbergen,
and D. Young

May 8, 1968

With the addition of the accumulator ring and the reduction of the booster rep rate to 5 Hz, the injection energy of the booster (linac energy) should be reexamined. Some of the injection energy dependent costs were identified and estimated. This was done at 6 values of the injection energy: 50 MeV, 100 MeV, 150 MeV, 180 MeV, 200 MeV, and 220 MeV. The results are tabulated below.

Table I. Linac

Energy (MeV)	50.0	100.0	150.0	180.0	200.0	220.0
Beam Current required for 4 turn injection (mA)	24.0	32.7	38.7	41.6	43.3	44.8
Momentum spread $\frac{\Delta p}{p}$ ($\times 10^{-3}$)	±1.73	±1.16	±0.93	±0.85	±0.80	±0.76
Emittance (mm-mrad)	9.21π	8.77π	8.37π	8.14π	8.00π	7.86π
Cost of linac + building (10^6 \$)	3.75	5.30	7.39	8.48	9.20	9.93

Table II. Booster RF

Injection Energy (MeV)	50.0	100.0	150.0	180.0	200.0	220.0
Frequency at Injection (MHz)	16.78	22.88	27.07	29.07	30.26	31.33
Frequency at 10 BeV (MHz)	53.24	53.24	53.24	53.24	53.24	53.24
RF cavity aperture (in)	4.30	2.93	2.32	2.08	1.95	1.78
Cost of booster RF (10^6 \$)	6.44	3.38	2.43	2.30	2.13	2.03

Table III. Booster Magnet and Power Supply

		50.0	100.0	150.0	180.0	200.0	220.0
Injection energy (MeV)		50.0	100.0	150.0	180.0	200.0	220.0
Protons per pulse ($\times 10^{12}$)		3.0	3.0	3.0	3.0	3.0	3.0
Emittance at injection for same space charge factor (mm-mrad)	V	79.5π	36.9π	22.9π	18.3π	16.0π	14.2π
	H	238.4π	110.6π	68.6π	54.8π	48.0π	42.5π
Emittance at 10 BeV (mm-mrad)	V	2.26π	1.50π	1.16π	1.02π	0.95π	0.88π
	H	6.79π	4.51π	3.47π	3.06π	2.84π	2.65π
Magnet Aperture	F Gap (in) × Width (in)	3.06×9.26	2.24×6.58	1.87×5.38	1.72×4.91	1.64×4.66	1.55×4.43
	D Gap (in) × Width (in)	4.11×6.44	2.98×4.58	2.47×3.79	2.27×3.48	2.16×3.32	2.06×3.14
Stored energy (MJ)		3.35	1.75	1.20	1.02	0.92	0.83
Cost of booster magnet and power supply (10^6\$)		11.15	5.83	4.00	3.38	3.06	2.76
Total cost of linac + building, booster magnet + P.S., and booster RF (10^6\$)		21.34	14.51	13.82	14.16	14.39	14.72

We see from these tables that the total identified cost has a minimum at a linac energy of about 140 MeV and rises only slowly toward higher linac energy. Before drawing any conclusion from this feature we should point out several other important considerations.

In the first place the increases of magnet aperture, stored energy and range of frequency modulation of the booster accelerator at lower injection energy imply, in addition to increased costs of the booster magnet and power supply and the booster RF as indicated in these tables, also reductions in reliability and performance of these components. In the second place, several other major linac energy dependent costs are not included in these tables. For example, excluded are the cost of the booster tunnel and equipment gallery, and the cost of the main accelerator together with its tunnel and associated buildings. While it is true that when closed orbit errors are corrected the acceptance of the main ring is adequate to accommodate even the largest beam emittance from the booster listed in the table, the tighter fit will definitely require more effort in alignment and correction of closed orbit errors of the main ring. Furthermore extraction of the larger beam from the main ring will impose more stringent and exacting demands on the performance of the extraction system. Altogether this means a reduction in reliability and performance of the main ring at lower linac energy if the design parameters of the main ring are kept fixed. On the other hand if the main ring parameters are scaled according to the beam emittance from the booster to keep the relative reliability and performance of the main ring unchanged the increase in cost of the main accelerator at lower linac energy will definitely override any cost reduction indicated in these tables.

These considerations lead to the design philosophy that within a reasonable range of the shallow cost minimum given by these tables higher linac energy is more desirable. An appropriate choice of the design energy of the linac is, thus, 200 MeV.